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WATER SUPPLY,

AND ITS

Relation to Health and Disease.

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WATER SUPPLY.

FROM the earliest times an abundance of pure water has been regarded by mankind as one of the most desirable of blessings. When men, in the progress of civilization, began to mass themselves together in cities, one of the problems which early demanded consideration was, how to supply themselves with pure water.

There were various sources of supply—from wells, from streams, and from rain-water stored in cisterns. Some cities, like Rome, undertook gigantic hydraulic works, building magnificent aqueducts to conduct the water from distant sources of supply into the imperial city. Jerusalem constructed vast cisterns hewed out of the solid rock, and filled them by subterranean conduits leading outside the walls of the city. The great importance of pure drinking water as a factor in the preservation of health is becoming more and more recognized by scientists and medical men. It is now generally conceded that impurities in water are more potent in the origin and spread of disease than any other cause, and that the germs of many of the more fatal forms of disease are introduced into the system by means of water. Epidemics of zymotic disease, as typhoid fever and diphtheritis, have so frequently been proved to have arisen from the use of contaminated water, that there is no question as to its influence. This is abundantly shown in the fact that so soon as the cause is removed the disease has abated. It is true that this class of diseases arises from other causes, but the use of impure water is one of the most frequent. It is asserted by some writers who deny the connection between the use of polluted water and the increase of disease that water known to be very impure has been used for years with immunity from any zymotic disease. Although much has been said *pro* and *con*, it is undoubtedly true that the weight of evidence favors the theory that polluted water may, and does, become the cause of disease, and therefore the great importance which writers on sanitary science attach to the subject, and the importance of educating the public to right views and practices concerning their water supply.

SOURCES OF SUPPLY.

There are five sources of supply; namely, springs, streams and lakes, rain-water, and wells, each possessing different degrees of purity,

and of various degrees of abundance. In regard to purity they rank as follows:

1. Springs.
2. Deep wells.
3. Rain-water.
4. Shallow wells.
5. Streams and lakes.

Springs found in suitable localities, and furnishing an abundance of water, are very satisfactory sources of supply. Their advantages are a uniform temperature, and freedom from contamination. Their disadvantages are, their liability to contain in solution an objectionable quantity of substances; as iron, sulphur, salt, etc. When furnishing a large amount of water they can be used to supply numbers of families by conducting the water through pipes to the places of consumption.

Wells are of two kinds—deep and shallow. The first furnishes the purer water, to reach which it is generally necessary to bore through impervious clay. The water is, therefore, thoroughly filtrated in passing from the surface of the ground to the spot reached by the shaft. If too deep, however, as in the case of artesian wells, the water is liable to contain an exess of inorganic matter; as salts of magnesia and lime. Shallow wells, if favorably situated, usually furnish reasonably pure water; but unless care is taken in the selection of the site they will become polluted by organic matter, finding entrance by soil saturation, from surface drainage, or through fissures in the strata of the ground.

It would be commonly supposed that rain-water collected in clean cisterns from well washed roofs would fill all the conditions of purity and wholesomeness; and it would do so were it collected at a distance from towns and villages. But rain-water collected in towns is far from pure. The water in falling carries with it many gaseous and solid substances with which the atmosphere is loaded. Roofs of houses are covered with dust, excrement of birds, fungus growths; and it is impossible, without the most vigilant care, to prevent these impurities from being carried with the water into the cisterns in objectionable quantities. It is asserted, also, with good show of reason, that the softness of the water, though admirable for cleansing processes, unfits it for drinking purposes because the structures of the body are largely supplied from the mineral constituents of water.

Streams and lakes or ponds are placed last for several reasons.

They are the natural drains of the territory through which they pass, receiving not only the rain-fall, but also all organic and inorganic matter washed into them by a thousand tributaries. After rains they become turbid with earth. They are the receptacles of all the waste products of the inhabitants of the district; they receive the contents of sewers, cess-pools and privies; the offal of distilleries, slaughter-houses and tanneries, and the refuse of factories. Into them are thrown carcasses of dead animals as the most expeditious method of burial. From swamps they receive the matter of vegetable decomposition, and are discolored by flowing over beds of peat. In the West the evil is not so serious on account of the low percentage of population to area, but some of our streams are beginning to show the effects of increasing population, and especially in the growth of towns of considerable size upon their banks. In the more densely populated districts of our Eastern States, and especially in parts of Europe, many of the streams are already hopelessly polluted, and the subject is eliciting the anxious consideration of sanitarians.

It is certain that until some method can be devised to utilize sewage, the offal and refuse of manufactories, slaughter-houses, and distilleries, streams must be the channels through which waste products may escape.

The objections to the use of the water of streams as a beverage are: the high temperature; its occasional turbid condition after excessive rains; and the great liability to contamination from organic matter and waste products of factories. From the difficulty of supplying large cities from any other source the question resolves itself into the problem of how to secure, under these unfavorable conditions, an adequate supply of wholesome water.

CHARACTERISTICS OF GOOD POTABLE WATER.

Absolutely pure water for domestic use is seldom to be obtained, and even if it could be, is hardly to be desired. Distilled water is unpalatable, having a flat, insipid taste. Indeed, water to be pleasant to the taste must contain in solution certain gases; and is not rendered unpalatable nor unwholesome by the admixture of mineral substances, unless these are in excessive quantity.

Waters which flow over or through granite and gneiss formations, are the purest, yet even these dissolve some mineral substances. The most common of these are the chlorides, sulphates, and carbonates of sodium, potassium, magnesium, and calcium, together with silica and

aluminum. Iron is the metal most frequently found. To the presence of these minerals is due that quality of water called hardness. For cleansing purposes it is objectionable; but it is an open question, whether hard or soft water is most beneficial to health. Nearly all water contains, also in solution, more or less of vegetable organic matter, due to the action of water on the vegetable matter over which it flows, or to vegetable growths which live and die in the water itself. Water flowing through peat formation is often highly colored, but is not, on this account, considered unwholesome. It is well known that water of this character is often selected for ocean voyages, on account of its power of retaining its freshness for long periods. In England and Ireland, bog-water is held in high repute for its excellence. So it will be seen that water need by no means be pure to be considered potable. Many of the substances held in solution by water can hardly be regarded as impurities, and their presence, or absence, does not affect the health of the consumer. What, then, shall be regarded as constituting pollution of water?

As has been already remarked, it is difficult to find water entirely free from organic matters; and when these are present to only a slight extent, they do not affect to any appreciable degree the quality. If, however, the organic matter held in solution in water exceeds a certain proportion, it becomes injurious to health, and in still greater quantity, dangerous to life. Of organic matter, the first in point of virulence are the dejections from human sources; and the most virulent of all are those from persons sick with zymotic disease. It has been well established that these diseases are communicated from the dejections of the sick finding their way into the stomach of the well. That water polluted with excrementitious matter alone can originate these diseases has been a matter of controversy, but that water polluted with execrementitious matter from persons sick with certain forms of disease will induce the same diseases, is a fact well established.

It has been argued by high authority that the reason of danger from organic pollution is, not that organic matter is harmful in itself, but that it serves as points of attachment and propagation of germs of septic diseases, and wherever there is organic pollution there also is danger of the presence of zymotic germs.

Second in point of danger is pollution from offal of slaughter-houses, and the refuse of tanneries.

Third, excrementitious matter from domestic animals; and lastly, from vegetable organic matter.

If the presence of decaying products from vegetation poisons the air, and causes malarious diseases, it would seem equally probable that their presence in excessive quantity in water used for drinking would give rise to the same evil.

Turbidity of water by itself can hardly be considered injurious to health, unless the quantity of earth held in suspension be considerable, and consists of clay, in which case constant use may bring on intestinal disturbances and indigestion. Turbid water, however, is liable to contain organic matter in excess, and hence due caution should be observed in its use.

We come now to the methods of preventing contamination of water and of removing impurities when present.

RAIN-WATER.

In many towns of small size, where it is impracticable to build water-works, on account of the expense, or the remoteness of the supply; and when well water contains an excessive quantity of mineral substances, and especially the salts of magnesia, many are driven to depend upon rain-water for domestic use. In the country, where the air is pure, and little dust, it is generally only necessary to cleanse the cistern once or twice a year to ensure sufficient purity in the water, but in towns, as we have already shown, there are many causes of contamination. A great many devices have been adopted to render the rain-water fit for use. The first to suggest itself, is to allow the first flow to escape, until the air, roofs, and pipes are thoroughly cleansed, and not until then allow the water to flow into the cistern. This would necessitate the use of self-acting valves, or of constant surveillance, both of which have been proven to be impracticable.

Another way is to cause the water to flow through walls, or obstructions which should remove objectionable matter, and render the water fit for use. A great variety of materials have been used for the purpose; as brick, porous tiles, vegetable and animal charcoal, compressed sponge, unglazed earthen-ware, sandstone, and spongy iron. Of all these, only two can be relied upon to any extent to remove or destroy organic material; namely, animal charcoal and spongy iron. The only objection to the latter is, that the water becomes more or less impregnated with the iron. One common method is to build a cylinder of brick in the center of the cistern, the water filtering through in suffi-

cient quantity; another, to divide the cistern into two divisions by a brick partition. Sandstone or porous tile may be used for the same purpose. The objections to all these materials are, that they soon become clogged and covered on the outside with a deposit of decaying organic matter, through which the water must pass to reach the inner chamber, and which must necessarily communicate some offensive property to it, or the water is arrested in its passage and the supply ceases. This is the most fortunate result, for it calls attention to the condition of the filter and necessitates removal or cleansing. It is also doubtful if these materials destroy organic matter.

Repeated experiments have shown that the best material for a filter is animal charcoal, used either in blocks or granulated. It has been demonstrated that this material destroys and removes organic matter. Blocks of the animal charcoal may be built up in cylinders, or partitions. A recent device is to attach the filtering box by coupling to the suction pipe of the pump, by which means it may readily be removed for cleansing or renewal. Whichever form of filter is used, it is advisable that it be thoroughly cleansed or renewed once in six or twelve months.

PURIFICATION OF WELLS.

As a large proportion of our population are dependent on wells for water supply, it is of the highest importance that they should learn the danger of pollution, and the most effectual methods of preventing it. We read in our journals of whole families dying in farm-houses of diphtheria, and the community wonders at the cause. Possibly no other cases occur in the neighborhood. With pure water, and pure air, these deaths would not have occurred. I do not think that men willfully disregard the laws of health, but they ignorantly violate these laws, and suffer the penalties of sickness and death.

I have placed wells as the second best source of supply, as regards freedom from organic pollution, when made with due regard to situation and surroundings.

Wells are of three varieties:

First—Those which are dug through deposits of soil, sand, and pervious gravel, until they reach a stratum of impervious clay.

Second—Those which penetrate the first stratum of clay, and passing through a bed of gravel or sand beneath the clay, reach another stratum of clay. These we may class deep wells, the first variety being entitled shallow wells.

Third—Artesian wells, penetrating the earth to considerable depth.

In wells of the first kind, the supply of water may at first be clear, bright, and sparkling, and reasonably pure. It undergoes a process of filtration, oxidation (because porous soil contains considerable air), and sedimentation, the earthy and organic matters being filtered out and destroyed in the slow passage of the water to the water-level of the well. But the householder is generally guided only by convenience in the location of his well. It is usually in the rear of the dwelling, in close proximity to the kitchen. The barn, the privy, and the cess-pool, if such there be, are also conveniently located near the house, and also near the well. Generally, no regard is taken of the slope of the barnyard or of the direction of the stratum of clay upon which the well rests. Excrementitious matter from the barnyard, or the refuse of the kitchen are washed into it; the contents of the cess-pool or privy gradually saturate the soil in an ever-increasing area, until they reach the well. It is not necessary to the contamination of the water that the area of soil saturation should reach the well. As water is drawn from the well, there is a movement of the water in the surrounding soil to fill up the void, therefore surface water passing through the area saturated with the organic matter will dissolve this matter and carry it into the well. After heavy rains it has been noticed that the water of shallow wells is more than ordinarily impure. In towns and villages, the probability of pollution is much increased, owing to the greater contiguity of cess-pools and privies to the well, and the greater quantity of refuse matter upon the surface.

WHAT ARE THE REMEDIES?

First—To lay the upper part of the well in cement, so as to exclude surface drainage.

Second—To pay due regard to the slope of the impervious bed, so that the direction of the underground flow should not be from the privy and barnyard toward the well.

Third—To place privies, cess-pools, etc., at a sufficient distance (not less than one hundred feet) from the well, so that if any organic matter reaches the well it will be so much diluted as to be innoxious.

Another means of safety is frequent cleansing of privy vaults and cess-pools, and disinfection of their contents. Slops should not be thrown near the well.

The question will be asked: What distance from deposits of filth

should the well be placed to insure non-pollution? It depends somewhat on the nature of the soil, and the direction of the impervious stratum beneath. Instances, well authenticated, are reported of the contents of privy vaults polluting wells situated a hundred feet from them. Usually, however, a distance of sixty or seventy feet insures non-pollution.

The water of deep wells, or such as derive their supply from underneath an impervious stratum of clay, and which penetrate a water-bearing bed of gravel or sand—this kind of well is less liable to contamination than the first, because it usually derives its supply of water from a distance, provided the surface, or ground water, does not obtain entrance. If the surface soil is clay, no precautions are necessary, except to raise the mouth of the well above the surrounding level. But if the well is first sunk through sand, or gravel, the wall should be well laid in cement above the first seam of clay. Occasionally, however, there is danger of organic matter reaching the well through fissures in the clay, and especially the kind known as joint clay. If this is suspected, the privy, or cess-pool, from which the filth comes, should be removed to a greater distance, and in a different direction from the well.

A new method which obviates many of the ordinary risks of pollution is called the drive-well system, familiar to every person in the Western States. The pipe being impervious to water, except at its lower end, no impurities can find entrance, save such as are present in the water-bearing stratum to which it penetrates. If sunk through surface sand, or gravel, to the first layer of clay, the water is equally liable to contamination, except from surface drainage.

A system for supplying water to towns of moderate size, situated on the margins of streams and ponds, has been practiced in Europe, and to some extent in this country. This consists in sinking one or more large wells near the bank of the stream, or pond. These wells are not supplied, as might be supposed, from the river or lake, as experiment has proved that the water will not filter through the bank in sufficient quantity, and attempts to obtain a sufficient supply from this source have proved a failure. Where, in the vicinity of a river or pond there is a sufficiently pervious soil, and especially where the land rises gradually from the river there is a body of ground-water moving slowly, and regularly, to the bed of the stream—if a well is sunk into this water-bearing soil, it intercepts and receives a portion of the water. A sufficient number of them, connected by galleries,

would undoubtedly furnish a large quantity of water. The quantity would be affected, however, by the porousness of the soil, its angle of declivity, and the amount of rain-fall. To supply a town from this source, the minimum amount entering the wells can only safely be calculated on. A well of this kind, sunk on the banks of the Elbe, where the soil was very porous, furnished 600,000 gallons every twenty-four hours. The pumping was so conducted as to keep the water in the well eight feet below its normal level.

The question has been raised whether the supply for the city of Des Moines could not be furnished from large pits sunk near the banks of the river, under the supposition that sufficient water would pass from the river into them to supply the city, but experiments of this kind, as before stated, have proved a failure. It is possible, however, that a sufficient quantity could be furnished from the ground-water moving toward the Raccoon River from the heights and along the bottom-lands. Waltham and Cambridge, in Massachusetts; Toulouse, Lyons, Nevers, and Blois, in France; and Dresden, in Saxony, are supplied in this manner. The water collected in this manner, or by natural filtration, as it has been termed, is generally harder than river water, but more free from organic matter; yet if this ground-water passes under a densely populated neighborhood, it is liable to pollution from percolation from privies, cess-pools, and other collections of filth existing in said locality.

RIVERS AND LAKES.

We come now to the examination of the water of rivers and lakes, and especially of the first named, as the source of water supply. Many of the large towns of this State derive their supply of water from this source, or are preparing to do so. Are the waters of our rivers of sufficient purity, when taken directly from them, to be healthful? or do they need some method of purification to render them fit for use? I have already stated the causes of pollution of river water. Many of these are not as operative in our State as in some others; yet, with the rapid increase in the number of slaughter-houses, soap manufactories, rendering establishments, and sewerage from large towns, the danger is increasing yearly. The source of pollution is also a most dangerous one; namely, animal organic matter, a large proportion of which is in process of decomposition. A very small quantity of this matter in water renders it inimical to health.

SELF-PURIFICATION.

There are three modes of self-purification of river water; namely, sedimentation, dilution, and oxidation. In addition, a certain amount of animal matter is consumed by fishes; a favorite place of resort for them being at the mouths of sewers. Aquatic plants also take up and assimilate considerable portions of organic matter.

SEDIMENTATION OR DEPOSITION.

Much of the waste matter thrown in streams is insoluble in water, and either sinks to the bottom, or is deposited on, or along the banks. Earths held in suspension are disposed of in this manner, so that a stream which is very turbid after heavy rains, soon becomes clear.

DILUTION.

This mode of self-purification is the diffusion of waste and excrementitious matter through the large mass of water, to such an extent that it becomes inappreciable to chemical tests. Sewerage, animal and vegetable matter, waste from factories, coloring matter from dye houses poured into rivers in quantities sufficient to render the water wholly unfit for use, are in the course of a few miles so largely diluted as to be probably innoxious. I say probably, for the reason that sanitary science has not yet determined to what extent polluted water must be diluted to render it fit to drink. Although a certain proportion of organic matter is destroyed by contact with air and light, and is consumed by fishes and plants, yet more or less still remains in the water for an indeterminate period.

OXIDATION.

It is undoubtedly true that in running streams, organic matter of certain kinds decomposes rapidly, and changes into harmless substances. Others are less easily decomposed, as muscular fibre, which may remain for months in water and still be recognizable under the microscope.

All water holds a certain amount of air, and in swift running streams the water is pretty thoroughly mixed with the air, and its oxygen unites with the organic matter in the stream, forming new combinations of nitrates, nitrites, and carbonic acid. Many examinations of the waters of streams have been made with a view to determine the degree of purification within a certain distance from the source of pollution. This largely depends upon the width, depth,

velocity of current, number and size of affluents, rain-fall, etc. The Mississippi would so quickly dilute and oxidize the sewage and excrementitious matters discharged into it from cities like Dubuque, Clinton, Davenport, Burlington, and Keokuk, that at a short distance below, the water would be apparently as pure as above them. While the same cities, on much smaller streams, would contaminate the water for a much greater distance. Of these examinations I append a few, as illustrative of the effects of dilution and oxidation. The following is taken from the *Chicago Tribune:*

EXCRETION IN THE RIVER.

"There is some discussion and inquiry as to the purity of river water from which cities are compelled to seek supplies. Nearly all cities empty their sewers, reeking with excretion, into adjoining rivers, by which it is floated through smiling valleys to other cities below. The natural view of the case would be, that it is injurious to the health of the country through which it passes, and that no city lower down the stream could use the water with safety to health. But science and observation have thrown light on this important question. To quiet some minds the following is given, from the *Boston Journal of Chemistry,* May 1:

"Ten years ago we published in the *Journal* the results of several careful analyses of the waters of Merrimac River in eastern Massachusetts. These waters were taken from the river at Haverhill, a point some eight miles below the last of the great manufacturing cities which line the banks of the river almost to its source. The cities of Lawrence with 40,000 inhabitants, Lowell with 60.000, Nashua with 15,000, Manchester with 50,000, are all upon this famous stream, and the excreta and filth of at least a half million of people, and the refuse from hundreds of immense mills, are poured into it constantly, day and night throughout the year. The waste from the mills is not only of a filthy nature, but a considerable portion consists of substances highly corrosive and poisonous; as acids, spent dyes, mineral salts, and caustic alkalies. The Pacific Mills at Lawrence are of vast extent, the largest in the world, employing about six thousand operatives, and the filth coming from this establishment would seem to be sufficient almost to poison the waters of the Atlantic Ocean. The waters examined were secured at a point, as had been stated, not more than eight miles below the outlet from these mills into the river, and at the season (July) when the stream is at a stage of water half way between

its maximum and minimum flow. The analysis showed a high degree of purity in the water, the organic and inorganic matter falling below four grains in the imperial gallon. Results of this nature, so unexpected, created doubts as to the accuracy of the methods of analysis, but they were fully sustained by repeated testing under all the modified forms known in chemical research.

"'Standing alone, these results would serve to show the remarkable capability moving water possesses of self-purification; but the fact is strongly established by researches in England made upon the streams which are polluted by wash from the large manufacturing towns and cities. The streams in England are small, there not being one of so great a volume as the Merrimac, which we regard here as a small river. The pollution of English streams is carried to an enormous extent, the water of many, at the outfall of the sewers of large towns, being actually offensive; as it passes down the river it blackens from formation of sulphide of iron; further on the black color decreases, disappears, and the river at last exhibits no signs of odor, color, or turbidity. Again, soon after the sewage has been turned into the river the sewage fungus appears; the banks are black. A short distance further the fungus vanishes, vegetation is luxuriant, fish abound, the river clears, and no trace of black deposit can be seen. Thus the river Soar at Leicester is black with sewage. At Loughborough, thirteen miles distant, the water is perfectly clear and fish are abundant. The Irwell at Manchester is polluted with every form of filth; in nine miles the offensive character of the stream has entirely disappeared; and so in many cases.

"At no time and under no circumstances have the waters of the Merrimac became so impure, even at the point where they flow through cities, as to destroy life. Fishes in considerable numbers are found in the river at all seasons, and in the spring, shad, salmon and alewives abound.'

"Great alarm was felt in Chicago a year ago because of the bad condition of the water obtained from the lake. The enormous amount of filth carried by the river into the lake had seriously contaminated the water as far out as the crib from whence the water used by the city was obtained. Examinations of lake water at various points were made to ascertain the area of pollution. The following is the report made by the chemist of the Health Department:

"A full report of the analysis of samples of water recently taken from the lake was made by Professor Paton, the chemist of the Health

Department on yesterday. It has been already stated in the *Times* that the professor found indications of decomposing animal matter in the water, but it was not then known from what points the several specimens were obtained. The complete report as now submitted is important as showing very satisfactorily where water may be obtained from the lake with the least liability to contamination by the city sewage.

"It shows that during the late period of high water in the river the lake was certainly contaminated at and about the crib. This contamination was greatest, at the time the samples were obtained, a quarter of a mile southwest by south of the crib; next, in the well of the crib, and the contamination seemed to grow less as the distance east or north of the crib became greater. It does not follow that the contamination was wholly from sewage—for some reason no samples seem to have been taken from the lake between the crib and the mouth of the river—but it would be difficult to convince those who drank of the water that it came from any other source. Samples were taken at varying distances from the shore as far north as Highland Park, twenty-two miles from the city. In these only small traces of free ammonia and little albuminoid ammonia were found. The water seemed to grow purer the further north the samples were taken, after passing the outlet of the Fullerton Avenue conduit.

"The following table gives some of the results. Samples were taken both from the surface and at or near the bottom of the lake at the point indicated. The figures relate to the samples taken from the bottom. The analysis of the surface water varied slightly. The impurity of the water is indicated by the amount of ammonia it contains:

WHERE TAKEN.	PARTS PER MILLION.	
	Free ammonia.	Albuminoid ammonia.
One-fourth mile southeast of crib	.36	.42
Well of crib	.32	.22
One-fourth mile east of crib	.16	.10
One mile east of crib	.10	.03
Two miles east of crib	.06	.07
One-half mile east of conduit	.07	.18
Two miles off Evanston Pier	Trace.	.08
Two miles off Grosse Point	.06	.11
One mile off Highland Park	.02	.11
Two miles off Highland Park	Trace.	.06

I also quote from the reports and papers of the American Public Health Association to show the effects of dilution and oxidation in the purification of even greatly polluted water:

THE SPONTANEOUS PURIFICATION OF RIVER WATER.

While the animal matters which find their way into wells from cess-pools and privies are capable of producing the fatal results to which I have called your attention, it is now well settled that such matters are speedily oxidized, and destroyed, and thus rendered harmless, when they flow into running streams, by the oxygen held in solution in the water. Dr. Alfred Taylor stated before the Parliamentary Commission that "organic matter in water is only offensive while in process of decay; when this operation is completed it ceases to be offensive.

Sewage which would poison an ordinary well becomes harmless in the running stream, and while the well is always open to suspicion, the river, though it drain populous districts, will, nevertheless, supply wholesome water. Having recently had occasion to study this question in connection with the project for supplying the city of Albany from the Hudson River, I have collected some facts and opinions which I will present to you as embodying the views of the most recent.

Dr. Frankland, in an article for the *Quarterly Journal of Science*, says:

The population in the basin of the Thames, above where water is taken, is 1,000,000, the drainage of some 600,000 of whom is poured into the river; the sewage is so thoroughly oxidized that no trace of it can be detected in an unoxidized state. The average flow of the river at the point where the companies take their supply is 800,000,000 gallons daily. The sewage contained would be $\frac{2250}{1000000}$.

The Royal Commission reports as follows:

But though for these reasons we believe that the organic contamination of the Thames is much less than is commonly imagined, still it would be sufficient to do great mischief were it not for a most beneficial provision of nature for effecting spontaneously the purification of the streams. Some of the noxious matter is removed by fish and other animal life, and a further quantity is absorbed by the growth of aquatic vegetation; but, in addition to these obstructions, important changes are effected by chemical action. The organic compounds, dissolved in water, appear to be of very unstable constitution and to be very easily decomposed, the great agent in this decomposition being oxygen, and the process being considerably hastened by the motion of the water. Now, as such waters always contain much air dissolved in them, the decomposing agent is ready at hand to exert its influence the moment the matter is received into the water; in addition to which the motion causes a further action by the exposure to the atmosphere, and when (as in the Thames) the water falls frequently over weirs, passes through locks, etc., causing further agitation and aeration, the process must go on more speedily, and more effectually. The effect of the action of oxygen on these organic matters, when complete, is to break them up, to destroy all their peculiar organic constitution, and to rearrange their elements into permanent inorganic forms, innocuous, and free from any deleterious quality. This purifying process is not a mere theoretical speculation. We have abundant practical evidence of its real action in the Thames and other rivers.

The following is the testimony of Sir Benjamin Brodie, Professor of Chemistry in the University of Oxford:

Oxidation is constantly going on in the soil and in the river; and, therefore, there must be some point at which the perfect destruction or oxidation of its animal matter must take place. What I think is much more important still, is another point; namely, the great dilution of the material; and I should rely upon the dilution quite as much, and more, than upon the destruction of the injurious matter. Supposing the sewerage of a large town, as Oxford, pouring into the river, there are numerous feeders and tributary streams to the river, which effectively dilute the sewerage. The sewerage is gradually getting less and less, and, therefore, its noxious character diminishes and ultimately disappears.

Testimony of Dr. Parkes, Professor of Military Hygiene of the Army Military School at Netley:

Q. Have you observed, in a case where sewerage has been discharged into a river, that after running three or four miles the effect of the sewerage has been destroyed?

A. Yes, we have; that in the case of the Southampton water supply. Some sewerage passes into the Itchen River, but it is quite destroyed by the time the water is distributed in Southampton; at least there is no detectable quantity.

Q. What is the distance?

A. The distance is six or eight miles. I could not undertake to state the distance in which water would purify itself in that way, but there is no doubt that it does purify itself, although in what distance, or in what time, or under what precise circumstances, I could not say.

Testimony of Mr. Leach, Engineer to the Thames Conservancy Board:

Q. How soon, in your observation, is the effect of sewerage destroyed by its flow and admixture with the water?

A. At Windsor, it is discharged into a most unfavorable point in the river, where there is little or no stream at ordinary times. The matter which is passed out of the drain, floats about in the river there to a very great and very disgusting extent. Two miles, or even a mile below, I could find no traces whatever of the sewerage.

Testimony of Mr. Hawksley, Vice-President of the Institute of Civil Engineers:

Q. You remember, do you not, the original condition of the river at Leicester, after receiving all the sewerage of the town into it?

A. Yes, perfectly well; at Leicester the water was as black as this ink. I do not mean to say that it was absolutely so thick, but looking at it in a mass, it was as black as ink; nothing would live in it, and the smell was abominable; but by the time it got to Loughborough, twelve miles below, it was entirely restored to its pristine condition; you could stand on the bridge, there, and see the fish swimming

among the beautiful reedy and other plants growing in the water, just as in the purest streams; you could see every pebble at the bottom; that is an instance of the effect of oxidation.

Testimony of Dr. Letheby, Medical Officer of Health in the Corporation of London:

Q. Taking the case of the cholera disease, and the discharges from the human body being mixed up with the sewerage, do you consider that any germs of that disease would be carried down in water?

A. At the present moment, we do not know what the germs of disease are; if the germs of the disease be decomposing matter, then I do not think that they exist in the water; but if the germs of the disease be living matter, then it is possible that they may exist in the water; but as nobody, as far as I am informed, can tell us what the germs of cholera are, it would be premature for me, or anybody, to theorize as to the probability, or the possibility of their existing in the water.

FILTRATION OF RIVER WATER.

The waters of Western rivers contain after heavy rains so much earthy and vegetable matter in suspension, that they are unfit for domestic use unless filtered. Different methods are in use to accomplish this purpose. The method practiced by the water company at Des Moines is, to sink iron cylinders, open at the bottom, in the channel of the river, and into the sand and gravel ten feet or more, the water being filtered by passing up into the cylinder through the stratum of sand and gravel at the bottom of the river. This method proved successful while the demand for water was limited, but at present fails to furnish clear water to the city, by reason of the want of capacity of the filtering chambers. Immediate steps will be taken to sink additional cylinders, when it is believed that a sufficient supply of clear water will be furnished to meet all demands.

Another method is, by passing the water over filtering chambers, the chambers being constructed of stone laid in cement, ten feet in depth, of length and breadth to furnish an ample supply of water. On these chambers is constructed the filtering bed.

In building this up, provision is first made for the ready collection of the water, by constructing upon the floor of the basin from which the water is to be filtered, into the chambers below, channel ways of stone or brick, laid dry; then follows a layer of broken stone, of three or four inches in diameter. This is succeeded by gravel, screened so as to be of uniform size (a layer of coarse being followed by one or more of smaller size); upon the gravel are placed layers of sand of different degrees of fineness. The filtering bed at Poughkeepsie, New York, has

a total thickness of six feet. The water flows over this bed to the depth of three or four feet.

The objection to this method is the necessity of frequent cleansing of the filter-beds. The more turbid the river the oftener must this be done. In the worst stages of some rivers, this has to be done as often as once a week. Another objection is the liability of the water in the basin to freeze to a great depth in severe winters.

Still another method of purifying water is storing it in large reservoirs, when the stream is clear, and drawing from this supply when the river is turbid.

LEAD POISONING.

Another and dangerous source of contamination of water, and especially of river water, arises from the use of lead pipe to conduct the water from the street mains to yards and houses. The oxygen in the water acts upon the lead, forming compounds which are injurious to health when taken into the system. Soft water is contaminated much more rapidly than hard, for the reason that the mineral constituents of the hard water soon form an impervious coating on the inner surface of the pipe. The water of Iowa rivers holds in solution considerable quantities of mineral matter, and lead pipes become speedily encrusted with them, especially with the sulphate of lime. Care, however, should be taken to allow the water to run long enough to discharge the water standing in the service pipe, before drawing for domestic use.

PURIFICATION OF WELL WATER.

When the water of wells is once polluted by the contents of cess-pools, or privies, it is difficult, or, I may say, impossible to purify it. Oxidation can do but little on account of the small amount of air held in suspension, and the limited exposure to the external atmosphere. Purification by dilution is evidently impossible. The only methods of purification are, by boiling, or filtering through animal charcoal, and it is doubtful if the latter mode is perfectly safe.

When a well is found to be polluted except from surface drainage, it should be filled up and a new one dug sufficiently distant from sources of contamination to insure pure water.

TESTS OF THE QUALITY OF SOIL WATER.

The Secretary of the State Board of Health of Michigan reports the following:

The question of the fitness or unfitness of soil water for domestic use can be absolutely determined only by a careful chemical analysis. But many persons who would not wish to incur the trouble and expense of a chemical analysis will yet desire some popular means of testing the water they use. The following methods of testing such water are presented, not as the most complete possible, but such as anyone can supply without the skill and appliances of the practical chemist. If such tests cast suspicion upon the quality of the water, and especially the water appears to cause sickness in any one using it, the water should be changed, or else a careful analysis should be made by some competent chemist.

Color—Fill a bottle made of colorless glass with the water; look through the water at some black object; the water should appear perfectly colorless and free from suspended matter. A muddy or turbid appearance indicates the presence of soluble, organic matter, or of solid matter in suspension. It should be "clear as crystal."

Odor—Empty out some of the water, leaving the bottle half full; cork up the bottle and place it for a few hours in a warm place; shake up the water, remove the cork and critically smell the air contained in the bottle. If it has any smell, and especially if the odor is in the least repulsive, the water should be rejected for domestic use. By heating the water to boiling an odor is evolved sometimes that otherwise does not appear.

Taste—Water fresh from the well is usually tasteless, even though it may contain a large amount of putrescible organic matter. Water for domestic use should be perfectly tasteless and remain so, even after it has been warmed, since warming often develops a taste in water which is tasteless when cold. If the water, at any time, has a repulsive or even disagreeable taste it should be rejected.

Heisch's test for sewage contamination.—The delicacy of the sense of smell and of taste vary greatly in different individuals; one person may fail to detect the foul contamination of a given water, which would be very evident to a person of a finer organization. But if the cause of a bad smell, or taste, exists in the water, the injurious effects on health will remain the same whether recognized or not. Moreover, some waters of very dangerous quality will fail to give any indication by smell or taste. For these reasons I attach especial importance to Heisch's test for sewage contamination or the presence of putrescible organic matter. The test is so simple that anyone can use it. Fill a clean pint bottle three-fourths full of the water to be tested, and dissolve in the water half a teaspoonful of the purest sugar—loaf or granulated sugar will answer—cork the bottle and place it in a warm place for two days. If in twenty-four to forty-eight hours the water becomes cloudy or muddy it is unfit for domestic use. If it remains perfectly clear it is probably safe to use.

OUTBREAKS OF ZYMOTIC DISEASES CAUSED BY USE OF POLLUTED WATER.

From the reports of the Massachusetts Board of Health of 1871 and 1876:

A somewhat extensive though mild epidemic of intestinal and gastric disease occurring in a hotel at Rye Beach, New Hampshire, was traced to the use of impure ice. The ice was taken from a pond in which was found a mass of decomposing material composed of marsh mud and sawdust. The water near this emitted an intolerable effluvium when stirred, and analysis showed a dangerous quantity of organic matter. On ceasing to use the ice the epidemic disappeared.

In December, 1865, typhoid fever appeared in Pittsfield, in a family of about forty persons, a boarding school for boys. The head of the school, and four boys, died. Eight or ten other cases recovered. The surrounding community was healthy. In this family, the water used was from a well under the wash-room. The drain from the wash-room was obstructed, and the foul water found its way under the floor, and into the shallow well. The well was closed, the family supplied with water from another source, and the fever subsided.

In illustration of the effects of drinking water made foul by decomposing organic matter, the following instructive facts are related by our correspondent at Sutton:

A large house in this village is supplied with water from a well in the front yard, three rods from the house. Connected with the house is a barn, without cellar, some three rods from the well. In December, 1868, a trench, three or four feet deep, was dug from the well to a point near the middle of the barn, where a pump was set, and a pipe connecting it with the well was laid in the trench; after which the earth, which was in large, frozen chunks, was filled back into the trench. In the house was kept a boarding-school for boys, of whom there were ten or twelve. Three little girls were also there, aged twelve, eight, and three years, belonging to the family of the owner of the house; there were, therefore, fourteen or fifteen children who drank from the well. The oldest boy was seventeen or eighteen years old, while the others were of ages from ten to thirteen. Everything went well until after the thaws in February and March, 1869, when the water had a decided taste and smell of stable-manure. March 26th one of the boys, thirteen years old, was seized with typhoid fever; another, twelve years old, on the 31st of March; another, eleven years old, April 2d; another, ten years old, April 4th, and another, twelve years old, April 9th. April 20th, one of the little girls, eight years old, was seized. Each of these six children (all of whom finally recovered) drank water with their meals, from the well in the yard. Some of the older boys drank coffee in the morning, and tea at night. The manner in which these children were attacked, and the fact that this house had been free from typhoid fever for many years, and the water heretofore known to be very pure and wholesome, leads me to the conclusion that the use of the water thus impregnated was the cause of the disease occuring where, and just at the time it did. My theory is, that while the ground, manure, etc., were frozen, the water was all right; but when it thawed, and the previously frozen filth leached through the soft and loose earth along the track of the pipe into the well, the effect of the poison was felt most perceptibly by those

who used the polluted water most freely, while those who used it less freely escaped entirely.

Our correspondent from Worcester says:

When I first came to Worcester there was a row of privies in Maple Street which drained into the wells near by, and typhoid fever raged until the use of the water was discontinued.

POLLUTION OF WATER FROM GRAVEYARDS.

Statements taken from the report of the Secretary of Michigan State Board of Health:—

Unfortunately, we need not go to France to learn what is the influence of graveyard water on the public health. In February, 1875, I received a letter from Dr. Chapman, of Grand Rapids, calling my attention to the serious sickness which had prevailed in families living on a certain alley in that city. From this letter I gather the following facts: There is a graveyard in Grand Rapids called the Fulton Street Cemetery. The soil in this cemetery to the depth of ten to fifteen feet is gravelly and sandy, and beneath this porous soil is a tenacious clay which dips to the east, toward the alley, on which are ten houses. The people living in these houses derive their water from wells, which penetrate two or three feet into this clay. In seven of these ten houses, severe sickness of a typhoid or typho-malarial type prevailed, the sickness lasting from fifteen to thirty-five days. In the family which has lived the longest on the alley, of six persons, five had the fever, three of them in a very severe form. Some of the wells were not more than twenty feet from graves. The impervious clay here served as a water-shed to convey the filtration of the graves directly into the wells, and these poor people were drinking a *cold infusion of death!*

ANALYSIS OF IOWA WATER.

I sent circulars some months since to superintendents of water-works in the State containing the following list of questions. Nearly all replied:

DES MOINES, June 10, 1880.

DEAR SIR—The State Board of Health desire information regarding the water supply of cities in this State. Will you answer the following interrogatories relative to your city?

1. What is the source of water supply?

2. Is the water filtered before entering pipes?

3. Are there any sources of contamination above the main pipes, as sewage, drainage from woolen-mills, slaughter-houses, etc.? If so, of what nature?

4. Has any analysis of the water been made? If so, give it.

Any other statements regarding your water supply, its purity, etc., will be thankfully received.

Very respectfully,

W. H. DICKINSON.

Committee on Water Supply.

I also requested the health officers of cities which have water-works to send samples of river and well water to Professor Pope, of the State Agricultural College, for analysis, together with such facts relating to possible or probable contamination of the water as he could obtain, such as characters of soil, depth of well, location of cess-pools, privy vaults, etc., and pollution of rivers from excrementitious and other matter, character of bed, banks, etc.

The results of the analyses and the statements of health officers and superintendents of water-works, are herewith submitted:

ANALYSES OF IOWA WATER.*

RIVER WATER.

LOCALITIES.	Free ammonia.	Albuminoid ammonia.	Chlorine.	Suspended matter.	Solid residue on evaporation.	Loss on ignition.	Total inorganic, or mineral matter.	Hardness in gr's. per U. S. gal. of 58.328 gr's.
1. Mississippi, Burl'n..	0.00080	0.01800	0.1691	8.9241	21.5396	2.4381	19.1015	6.22
2. Mississippi, M'c'tine	0.00230	0.01280	0.1166	0.8457	8.2825	2.5081	5.7744	5.81
3. Mississippi, Dav'p't.	0.00510	0.01760	0.0786	1.7731	13.7070	1.8314	11.8756	7.47
4. Mississippi, Clinton.	0.00155	0.02331	0.2740	6.4160	15.6780	2.5420	13.1350	5.81
5. Iowa, Marshalltown	0.00130	0.00990	0.0729	2.6830	16.9151	1.9831	14.9320	11.62
6. Iowa, Anamosa....	0.00340	0.01100	0.1048	....	....	.....	....	5.39
7. Cedar, Cedar Rapids	0.00000	0.01200	0.0991	3.6863	14.1153	1.9014	12.2139	9.13
8. D. Moines, Ott'mwa	0.00230	0.02330	0.1604	22.2462	33.9468	3.7329	30.2139	4.56
9. Raccoon, Des Moines	0.00150	0.00750	0.1137	0.2041	9.1574	0.6766	8.4808	8.30
10. Missouri, C. Bluffs..	No	report	rece'ed					

SHALLOW WELL WATER.

All wells not sunk below rock formation, or impermeable bed of clay, are deemed shallow wells.

11. Marshalltown......	....	....	15.0743	....	60.9527	.....	52.2320	43.98
12. Anamosa (E. Booth)	....	....	3.8903	....	32.3137	.....	25.6643	21.58
13. Anamosa..........	....	....	1.2043	....	15.6319	.....	12.1613	8.30
14. Ced. Rapids (2d w'd)	....	....	5.0220	....	55.2366	.....	49.3454	20.41
15. Ced. Rapids (1st w'd)	....	....	9.4374	....	65.8523	.....	56.0533	31.85
16. Ottumwa.........	....	....	4.0946	....	34.2385	.....	30.0389	17.01
17. Clinton...........	0.01920	0.04720	1.0980	....	32.8960	.....	26.9470	26.56
18. Burlington........	....	....	5.1037	....	50.4537	.....	43.7450	46.89
19. Des Moines........	0.00120	0.00260	3.5405	....	49.6711	.....	43.8393	39.84
20. Des Moines........	0.00310	0.00870	4.4486	....	75.9663	.....	69.9003	58.10
21. Davenport.........	0.00150	0.00730	2.8880	....	43.8393	.....	40.9229	26.56
22. Muscatine.........	....	....	10.1009	....	54.0700	.....	46.4874	40.18

DEEP WELL WATER.

23. Dubuque..........	....	....	0.1883	....	13.0071	0.8171	12.1900	17.01
24. Dubuque..........	....	....	0.2482	....	14.8386	1.0149	13.8938	19.09
25. Dubuque..........	....	0.00170	0.2041	....	14.4886	0.9448	13.5438	19.09
26. Dubuque..........	....	....	8.9970	....	41.2378	.....	32.8036	34.03
27. Des Moines........	0.00230	0.00230	1.9239	....	48.6398	.....	43.0927	39.84
28. Des Moines........	0.00690	0.00350	4.8062	....	42.4794	.....	37.6798	31.54

ICE WATER.

29. Mississippi River...	0.01550	0.01130	trace	....	1.3765	0.9449	0.4316	0.
30. Des Moines River..	0.01240	0.00310	trace	....	0.6998	0.2333	0.4666	0.
31. Des Moines River..	0.01390	0 00190	trace	....	0.7582	0.2916	0.4666	0.

*Analyses made by Prof. T. E. Pope, of Iowa State Agricultural College. The results are expressed in grains per U. S. gallon of 58.328 grains.

WHERE SAMPLES WERE COLLECTED.

RIVER WATER.

WATER-WORKS, BURLINGTON.

1. Source of supply, Mississippi River; distributed by Holly system; water filtered before entering the pipes; no source of contamination above main supply. Sample collected June 24.

WATER-WORKS, MUSCATINE.

2. Distance from source to point where sample was collected 1,100 feet. Two streams, having several slaughter-houses on their banks, enter the river above the water-works conduit pipes; also several sewers. An iron conduit pipe projects 700 feet into the river, fourteen feet below low water mark, through which the water is pumped into the reservoir which supplies the street mains. Sample collected June 24.

WATER-WORKS, DAVENPORT.

3. Sample collected August 13, from hydrant supplied by water-works. The water is taken from Rock Island Rapids, about one-half mile above the termination, where the current is very strong, by means of conduit, which runs some distance out into the river. No filtration.

WATER-WORKS, CLINTON.

4. Sample taken from hydrant at Lee's drug store, corner Fifth Avenue and Second Street, September 6, 1881. Water is pumped from Mississippi River. The conduit extends far into deep, quick current, and before reaching the pumps passes through two feet of sand and gravel. No contamination above the works except ordinary surface drainage. The city sewers are all below the pumping works.

WATER-WORKS, MARSHALLTOWN.

5. Supplied from Iowa River; water pumped into reservoir, which supplies street mains. Sample collected from hydrant, June 18. Water is filtered. No sewerage or other animal polluting matter known to gain access to the river above the water-works conduit pipe.

WATER-WORKS, ANAMOSA.

6. Water pumped into reservoir. Sample taken from hydrant June 22.

WATER-WORKS, CEDAR RAPIDS.

7. Water pumped into street mains direct through conduit pipes which enter the river above the city. Water not affected by anything except ordinary surface drainage. Street mains also supplied in part from a well. When water is drawn from the well, it is filtered. Samples taken from a hydrant, July 6, but whether it is from the river or well is not reported. The analysis indicates it is from the river.

WATER-WORKS, OTTUMWA.

8. Water is pumped into a reservoir, which supplies the street mains. Samples taken from hydrant on Main Street June 29. Several packing and slaughter-houses, from which the offal enters the river, about a half a mile above the pumping works.

WATER-WORKS, DES MOINES.

9. Supply taken from a filtering tank fourteen feet below the bed of Raccoon River, and pumped directly into the street mains by the Holly system. Sample taken from hydrants one-half mile from the river July 16. No contamination of water above the source of supply by sewage, manufactures or slaughter-houses.

10. No report.

SHALLOW WELL WATER.

11. Well fourteen feet deep; soil, loam; subsoil clay, yellow, friable, and porous; water-bearing strata is gravel and sand. Sample taken June 24.

12. E. Booth's. Depth, thirty-five feet; walled with stone.

13. J. C. Deitz. Same as No. 12.

14. Located in the Second Ward. Depth, sixteen feet; diameter three and one-half feet; cribbed with pine lumber, and walled with stone inside of cribbing, black loam six feet; yellow sand eight feet; coarse gravel and sand water-bearing strata two feet; several privy vaults eight feet deep, fifty to sixty feet distant; water raised with an iron pump. Sample collected July 6.

15. Located in First Ward, half mile distant from foregoing No. 14, and 400 feet from the river; livery stable directly in the rear;

nearest privy fifty to sixty feet. Soil and depth the same as No. 14, except the loam which is only a few inches in depth; more water drawn than from any well in the city. Samples collected July 6.

16. Depth twenty-five feet; water raised with a bucket; location on fourth street from the river, at the foot of the bluff; soil drift; no contamination by sewerage, drainage, or surface water. This well is one of the oldest in the city, and a fair sample of the natural water of the city.

17. Clinton. Sample taken from school-house well between Sixth and Seventh Avenue, Fourth Street, September 6, 1881.

18. No description received.

19. Driven well on bottom-land, corner of West Sixth and Market streets. Soil, drift, depth twenty-two feet; an old cellar filled with rubbish twenty feet distant; privy without vault, fifteen feet distant; back of residence fifteen feet distant, where all slops from kitchen are thrown. Sample secured July 19.

20. Location corner of East Third and Elm streets; two blocks from the Des Moines river; open; drift soil; depth of well twenty feet; depth of water five feet; several back doors of residences six and nine feet distant, where kitchen slops are thrown; two privies without vaults forty and fifty feet distant. Sample collected July 19 by lowering glass bottle to the bottom of the well.

21. Open; depth of well twenty feet; diameter four feet; soil, black loam, yellow and black clay and gravel, the latter being on a level with the river bed. The water in this well rises and falls with the river; privies fifteen and twenty-five feet distant. Sample collected August 13.

22. Depth of well twenty-five feet; diameter four feet; distance from drains and cess-pools, sixty feet; soil, clay; subsoil, sand; water-bearing strata, sand and gravel. Sample collected June 24.

DEEP WELL WATER.

ARTESIAN.

23. Depth, 1,600 feet; diameter, six inches; water rises to within thirty feet of the surface. Sample collected July 7.

WATER-WORKS AT DUBUQUE.

24. The supply comes from a tunnel or adit about one mile in length, penetrating the bluffs and running a due west course, varying in depth from the surface from one hundred to two hundred feet, and

sixty to eighty feet below the mineral bearing strata. Much of the distance is through solid rock, with frequent openings and fissures, through which the water is constantly forcing its way and the supply increasing. The tunnel is located about two and a half miles out of the city. A large reservoir about four hundred feet below the mouth of the tunnel, of the most substantial character, fully enclosed with heavy walls, shutting out all surface water, gives a storage capacity of about three million gallons, including the tunnel. The connection is made from a twelve-inch water main leading from the mouth of the tunnel to the city, running parallel with the reservoir and entering at the bottom, thus giving it the effect of a boiling spring. Sample collected July 7, from the tunnel or level.

25. Sample taken from a hydrant July 7, two miles distant from the reservoir.

26. Depth, thirty-five feet, of which six feet are limestone and slate formation.

27. Location, 838 West Fifth Street (F. Geneser); open, tight curb, roofed; brick wall; depth of well, forty-five feet; depth of water, twenty-one feet; soil, alluvial, one and one-half feet; yellow joint clay, twenty-one feet; gravel, one and one-half feet; blue and yellow clay, fifteen feet; sandstone, two and one-half feet; yellow clay, three and one-half feet; street, one hundred feet east, four feet above the mouth of the well; stable and three privy vaults, sixty, forty and thirty feet distant westward; privy vaults, ten feet deep, and bricked loose without drains; descent from the well to privy vaults and stable three to five feet; no slops thrown on the lot. Sample collected July 19, by lowering a bottle to the bottom of the well.

28. Location on Center Street between Fourth and Fifth; open; depth, thirty-five feet; depth of water, one hundred feet; soil, joint clay; no surface drainage can get entrance; privy vaults, twenty, forty-five, fifty and sixty feet distant. Water raised by wooden bucket. Sample collected July 19, by lowering a glass bottle to the bottom of the well.

ICE WATER.

AT DAVENPORT.

29. From ice taken at Davenport near the river channel in the lower part of the city, and below the city sewers.

AT DES MOINES.

30. From ice taken July 19, from a delivery wagon of Des Moines Ice Company (Grefe); melted by sun heat in a clean, new, earthen jar, and transferred to glass bottle. The ice was taken from Des Moines River above the dam.

31. From ice taken from the delivery wagon of Capital City Ice Company, at Des Moines the same date, and prepared in the same manner as No. 30. The ice was taken from Des Moines River below the dam.

REMARKS.

For the information of the general public, it may be said in explanation of the foregoing table, that the presence of albuminoid ammonia and chlorine in drinking water is regarded with suspicion. Albuminoid ammonia comes from pollution by sewage or excrementitious and vegetable matter. Chlorine is a constituent of common salt, hence, at a distance from sea-water, its presence in drinking water indicates contamination by drainage from privies and stables or urninary sources. According to Frankland, the celebrated English chemist, water containing .55 parts, or grains, or less of chlorine per United States gallon of 58.328 grains, may be regarded as pure and healthful, while water containing 2.7 parts, or grains, or over, should be rejected for drinking purposes.

While this may be true as a general rule, it will not apply strictly to Iowa, where the earth is rich in chlorides and sodium, so that a sample of water entirely free from possible contamination by surface drainage may contain chlorine, and yet not be objectionable for drinking purposes. So, also, as to albuminoid ammonia. What would apply to rivers would not apply to deep and shallow wells. Some rivers are entirely unpolluted by sewerage or manufacturing establishments. It is well known that peat abounds extensively in Iowa. Rivers receiving the drainage therefrom would show the presence of albuminoid ammonia in their water, yet it would not be objectionable for drinking purposes. It is very important, in making an analysis

of water, to know the geology and topography of the district supplying the water. In this the collectors of samples sent for analysis have been unfortunately neglectful in obeying instructions given.

The suitability of potable or drinking water for use must be decided chiefly from the proportion of organic matter or elements it contains. In deep well or spring waters, however, little importance is attached to this, for the reason that in such waters the organic elements may be derived from vegetable and not animal sources. Water from deep wells and springs usually shows the smallest amount of organic matter, the thick strata through which the water has passed having destroyed by oxidation most of the organic matter.

Upland surface waters in uncultivated districts are least liable to contamination from animal excreta, the organic matter contained in them being almost entirely vegetable, and usually peat.

Shallow well water is always largely dependent on the surroundings of the well. Such wells are, with few exceptions, polluted by animal matter. The water-bearing strata may be powerful enough to destroy and oxidize much of the polluting matter, but when overtasked, the purification is slight, and the water necessarily becomes, and often is, as unfit for use as that from a common sewer. Of the shallow wells shown in the above, No. 13 comes nearest the standard of purity. All others are objectionable in chlorine, especially Nos. 11, 15, and 22.

Of the different varieties of waters, the best for dietetic purposes are spring and deep well waters. Sample No. 26 would appear to be an exception. Although classed in the deep wells, the analysis indicates an extensive pollution by excrementitious matter, probably through fissures in the limestone rock.

Dr. Charles Smart, in his report to the Medical Director of the United States army, May, 1876, on spring, well and river waters, of the Department of the Platte, says the water examined at eighteen military posts contained free ammonia 0 to .98 parts per 1,000,000; albuminoid ammonia .10 to .98 parts per million. Lodge Pole Creek, of albuminoid ammonia, .19; Black's Fork, of albuminoid ammonia, .20; Douglas's Brook, of albuminoid ammonia, .28. Snow just fallen at Fort Bridger yielded .30 parts per United States gallon of water, had .50 parts per million of albuminoid ammonia, equal to .029 grains or parts per United States gallon of 58.328 grains. The albuminoid and free ammonia in the water of these far western streams, whose sources are clefted rocks, comes from dead vegetable matter along their banks, yet these streams are deemed to be the purest water

known. English authorities would condemn them as dangerous. Dr. Smart concludes that where the free and albuminoid ammonia is of vegetable origin, as in most of western waters, .30 parts per million, or .029 grains per United States gallon is allowable.

The inference to be drawn from the investigation of Dr. Smart is, that no definite standard can be made by which to fix potable water for dietetic use, so as to say that a water may contain so much, if it contains more it is bad; for where a certain amount of the same substance in one case indicates a fearful contamination, in another it would be harmless, or indicate only the normal constituents of the water. As has been stated, the geology and topographical surroundings in each case must be considered in deciding the suitability of any water. As a general rule it may be said river waters are the most objectionable from their liability to pollution by the refuse sewerage of towns. They are the natural carrier of all waste matter which in solution can be carried along by the current. No river water should be used for dietetic purposes without thorough and complete filtration.

ICE WATER.

POPULAR IDEAS.

Water from ice is generally considered pure and healthful. The notion that ice purifies itself by freezing is fallacious, and cannot be supported by scientific observation. Organic matter suspended in water would certainly be drunk by any person using the ice in the ordinary method. Ice should never be taken from water which is unfit for drinking purposes. Of the samples given in the foregoing table, No. 29 is objectionable. The other two are remarkably pure. The difference in favor of No. 31, may be accounted for by the fact that the water above the dam is still, having very little current, and therefore holds in suspension more organic matter than the water below the dam, where is a strong current, which together with the rapid plunging of the water over the dam would tend to oxidize or remove the impurities of organic matter in the water.

It should be borne in mind that all the foregoing samples of river water were collected when streams were swollen by floods and the waters turbid.

Des Moines, Iowa, *November 5, 1881.*